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WOODWASTE INCINERATION AND AIR QUALITY

IN

WILLIAMS LAKE

JANUARY 1988

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Preface

In June 1987, the Honourable Bruce Strachan, Minister of Environment and Parks, indicated an investigation of alternatives for controlling emissions from woodwaste burners in Williams Lake. This report provides an engineering analysis of the impact of the existing woodwaste disposal practices on the air quality in Williams Lake, and an overview of technological solutions to the problem.

R.G. Wilson
Director
Air Management Program

1.0 Introduction

Since the discovery of fire, man has been aware of the delights as well as the difficulties of burning wood. Even today depending on the locale and circumstances it is either used cleanly or burned in a less than desirable manner. Wood residues generated during various phases of its processing have different meanings to different people. Depending on the circumstances some regard it as a "waste" to be disposed of, while others consider it as a source of energy. However, the economics and the technology of using woodwaste as a fuel or feedstock are anything but static.

In Williams Lake a large quantity of woodwaste generated at the sawmills is burned inefficiently in several wigwam burners. The emissions of smoke and particulates from these burners have been adversely affecting the air quality. The dustfall level in the area exceeds the acceptable limit, and there is growing concern over emissions of fine inhalable particles and trace organic compounds. It is recognized by all concerned, including the sawmill owners themselves, that there is an air pollution problem in the area which deserves prompt corrective actions.

In preparing this report, the available information on the existing situation in Williams Lake has been reviewed. Because of the similarities of this situation with that in Quesnel in the late 1970s, the reports dealing with the latter have also been consulted. The local millowners have provided additional data as required.

Environmental regulations on woodwaste disposal and utilization in several jurisdictions were reviewed and followed up wherever necessary by personal contacts. A literature research on woodwaste combustion and conversion technologies was also carried out. In addition, several woodwaste utilization plants were visited and a number of meetings were held with the plant designers, operators as well as equipment suppliers.

On the basis of the information thus gathered several short-term options and two long-term options have been outlined. Because of the limited time no new economic analysis of these options has been carried out, instead the available information is updated. The major constraints to implement some of the options are identified, and several measures to overcome those are recommended.

2.0 Situation in Williams Lake

The air quality in Williams Lake has not been satisfactory with respect to particulates and smoke emissions in recent years. The contributory sources to this deterioration of air quality are largely the woodwaste burners used in the local mills to incinerate the excess residues. The City of Williams Lake is in a unique situation of having seven lumber processing mills incinerating over 2.1×10^6 m^3 of bone dry woodwaste every year in eight wigwam burners. Until recently,

there were nine such burners. All these burners were located within a stretch of about 8 km, in close proximity of residential and commercial areas, as shown in Figure 1.

2.1 Air Quality

Most of these burners have been in operation for several years. The permits under the old Pollution Control Act were issued to these burners during the period 1972-1979. The performance of these burners has been monitored by measurement of opacity of the discharge and the burner temperature. In addition, the air quality in the area has been monitored at several locations for dustfall, as the only viable method to ascertain the impact of emissions from the burners on the receiving airshed.

Dustfall monitoring data indicate that the levels have been exceeding the permitted levels in several areas of the city. Typical trends in the dustfall level in several locations are shown in Figures 2 and 3. It should be noted that the dustfall value at any location reflects the average monthly level, which is influenced by several factors such as variations in the emission rates and the prevailing wind speed and direction, etc. Therefore, at any given time the actual dustfall level at a location could be much higher or lower than the monthly average value.

The visible emissions of smoke and particulates, the presence of significant amount of combustibles in the

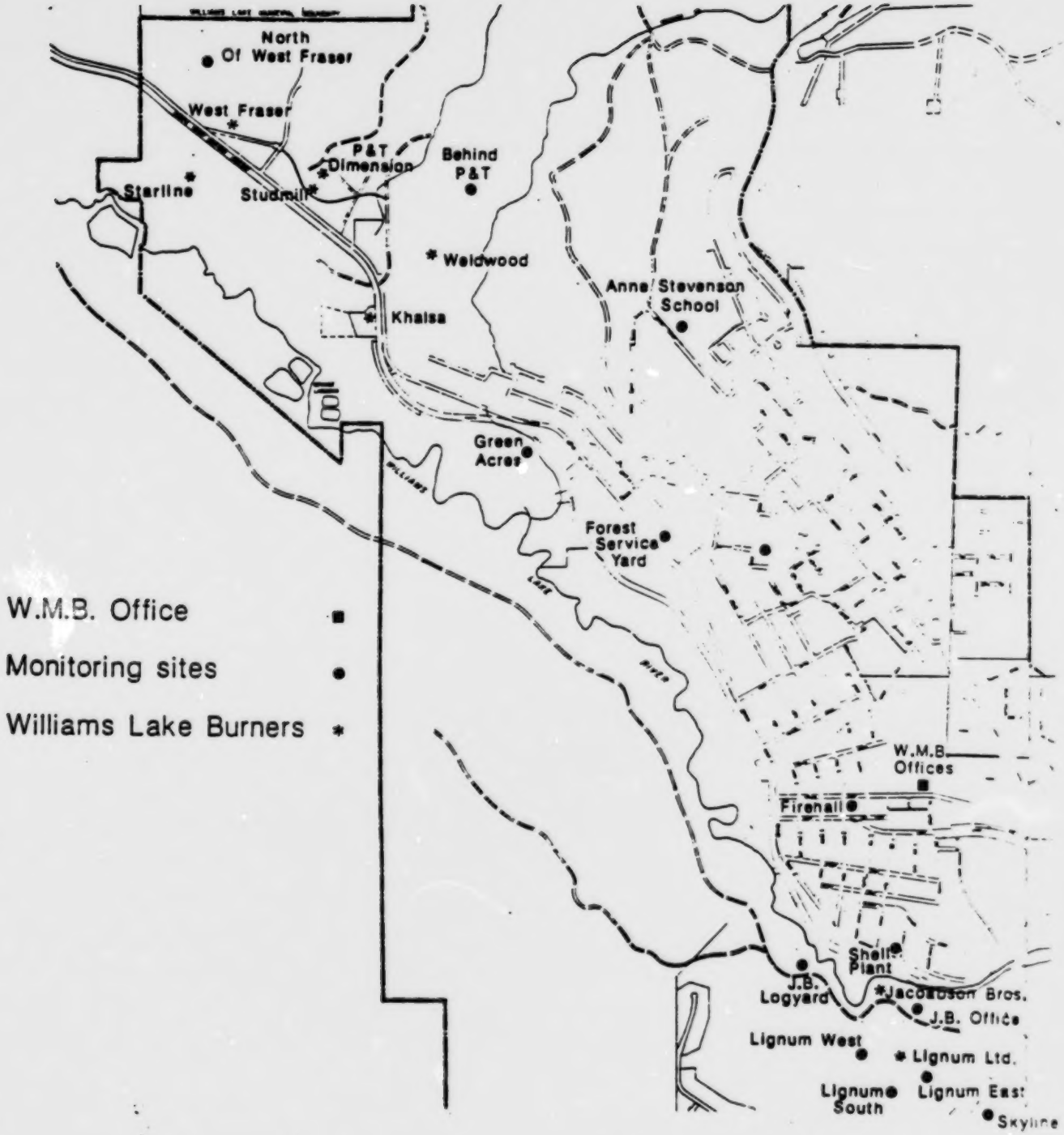


FIGURE 1: Locations of Woodwaste Burners and Dustfall Monitoring Stations

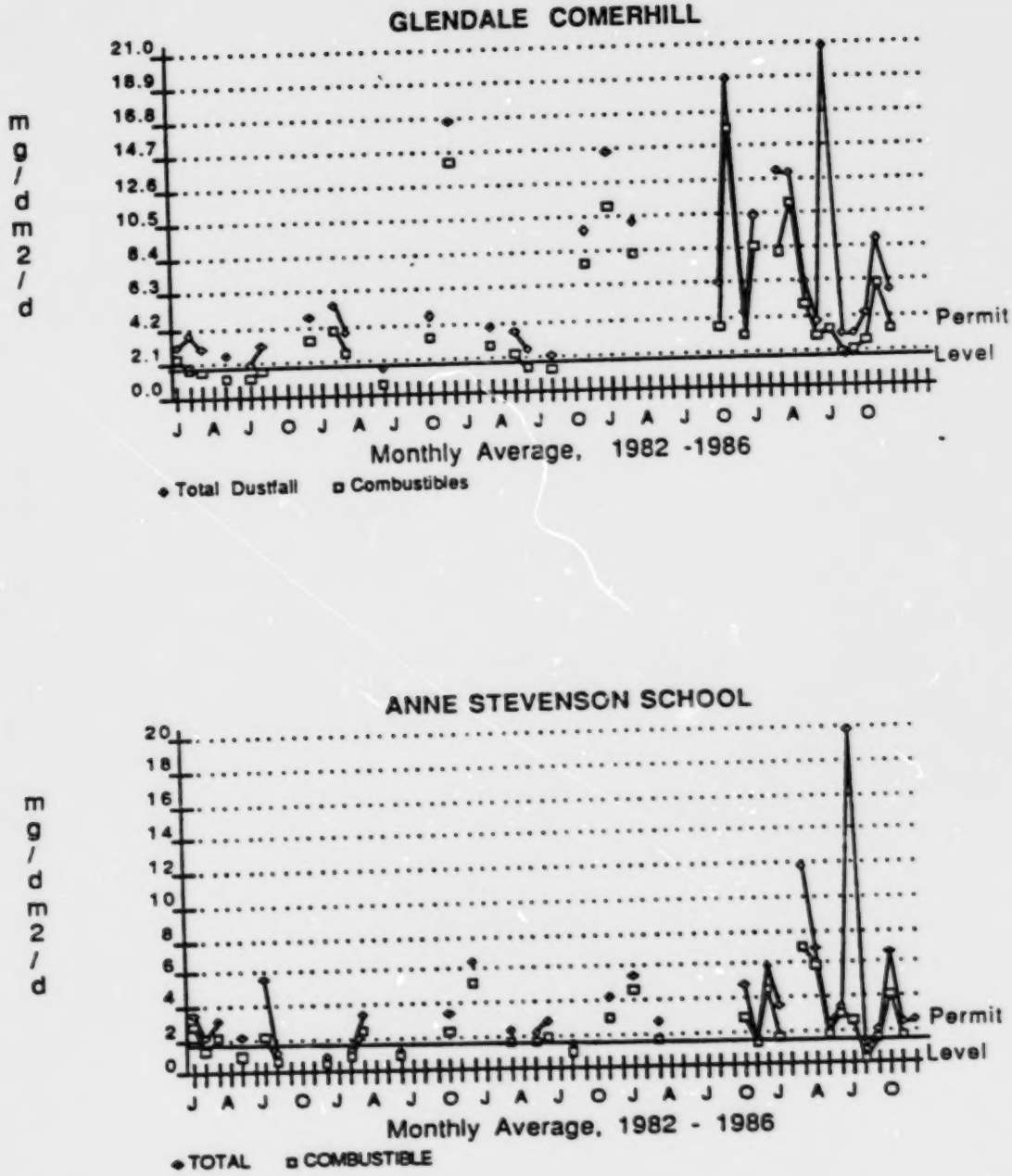
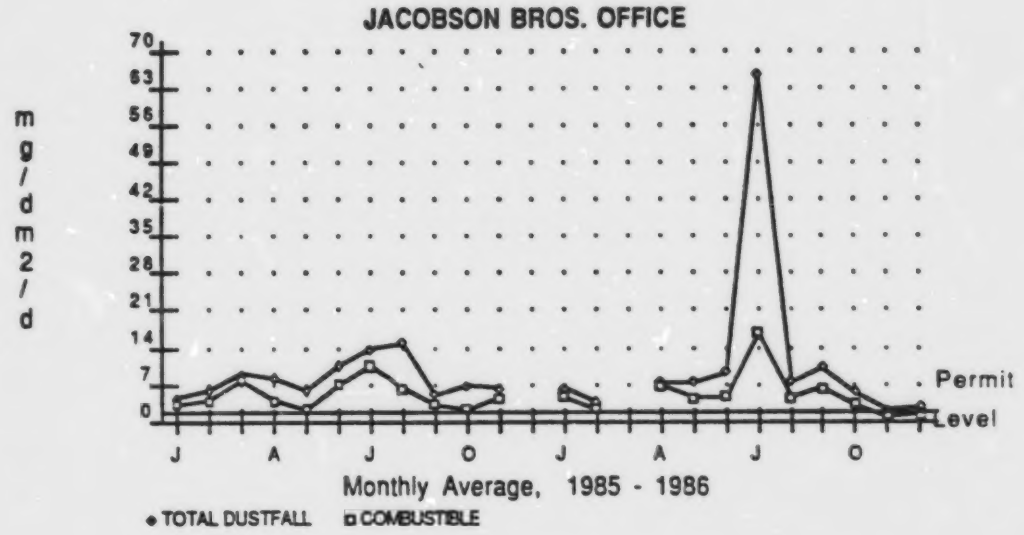


FIGURE 2: Trend in Dustfall Levels in Williams Lake



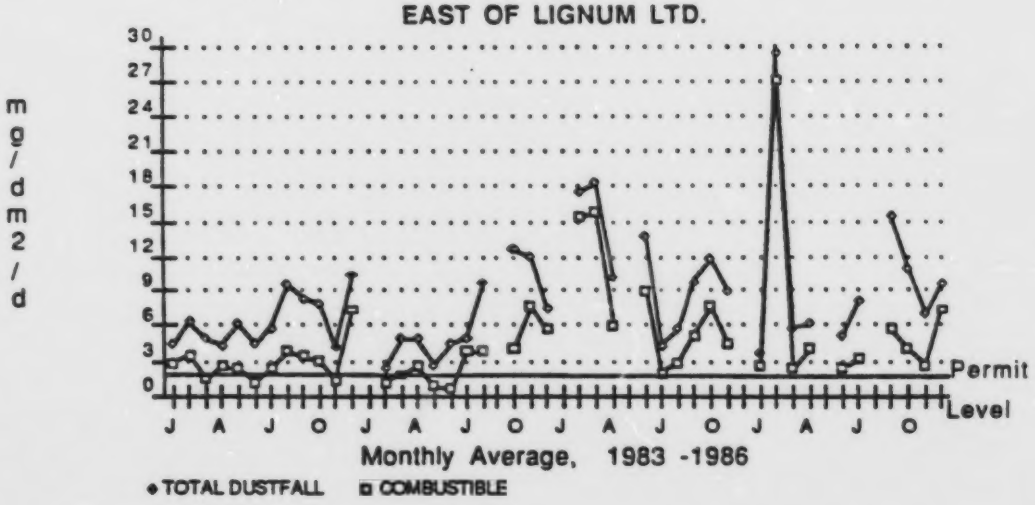


FIGURE 3: Trend in Dustfall Levels in Williams Lake

dustfall, and the deposition of fly ash and unburned char clearly demonstrate that the air quality in the area is adversely affected by the emissions from the woodwaste burners. In recent months the monitoring of fine inhalable particulate matter and polycyclic aromatic hydrocarbons (PA's), known toxic contaminants, has also been initiated at certain locations. The limited data indicate that fine inhalable particulates levels may be of some concern, but no conclusive statement can be made about PAHs at present.

2.2 Woodwaste Generation and Disposal

A significant quantity of residues is generated at various stages of the processing of logs during lumber production. Typical residue generation flowsheet is shown in Figure 4 for an interior mill in British Columbia.

The status of woodwaste generation and its fate from the mills in the area is shown in Table 1. It is to be noted that the data in the table have been provided by the Williams Lake Burner Committee, a committee of millowners and managers, as estimated in 1985. This is the latest comprehensive woodwaste survey information presently available, and is based on a total production of 794,839 MFBM* equivalent products from all mills. The generation of woodwaste, however, varies considerably from year to year due to a number of factors.

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* MFBM is one thousand "foot board measure", the most common unit used in the industry. One foot board measure of lumber is 1 in. thick x 1 ft. wide x 1 ft. long piece of wood.

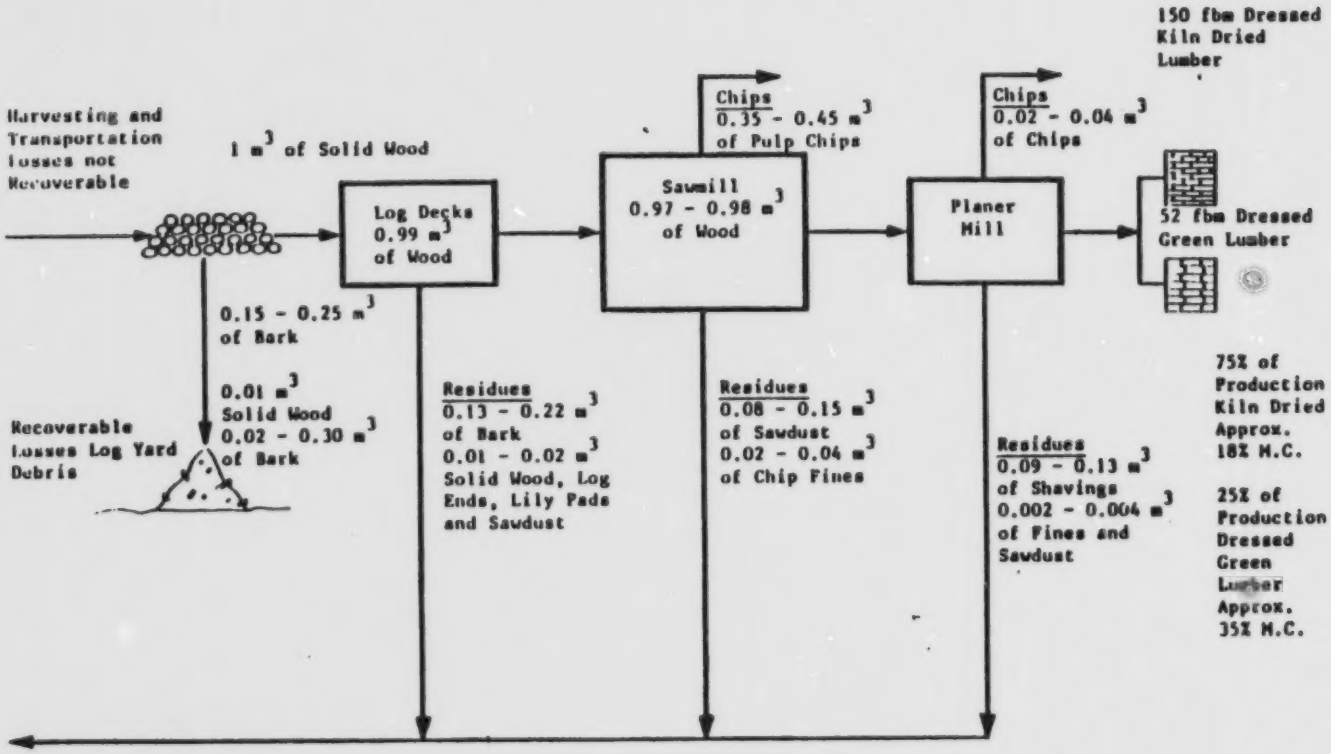

Harvesting and Transportation losses not Recoverable
1 m³ of Solid Wood
Log Decks 0.99 m³ of Wood
Chips 0.35 - 0.45 m³ of Pulp Chips
Sawmill 0.97 - 0.98 m³ of Wood
Chips 0.02 - 0.04 m³ of Chips
Planer Mill
150 fbm Dressed Kiln Dried Lumber
52 fbm Dressed Green Lumber
0.15 - 0.25 m³ of Bark
0.01 m³ Solid Wood
0.02 - 0.30 m³ of Bark
Recoverable Losses Log Yard Debris
Residues 0.13 - 0.22 m³ of Bark 0.01 - 0.02 m³ Solid Wood, Log Ends, Lily Pads and Sawdust
Residues 0.08 - 0.15 m³ of Sawdust 0.02 - 0.04 m³ of Chip Fines
Residues 0.09 - 0.13 m³ of Shavings 0.002 - 0.004 m³ of Fines and Sawdust
75% of Production Kiln Dried Approx. 18% M.C.
25% of Production Dressed Green Lumber Approx. 35% M.C.

FIGURE 4: Typical Western Softwood Sawmill Residues Flowsheet for $1m^3$ of Solid Wood Through the Process.

SOURCE: ENFOR PROJECT C-258

As shown in Table 1, only about 14% of the total woodwaste is utilized in two of the mills for energy recovery. The portion of woodwaste utilized in one mill is over 52%, while in the other it amounts to approximately 16%. Hence the bulk of the woodwaste generated in Williams Lake mills is disposed of by incineration.

In addition, an estimated total of approximately 66,000 m^3 of woodwaste, mostly from the mill logyards, is permitted to be landfilled after open burning. The major portion of this is sent to an off-site landfill, while the remainder previously has been burned on site prior to disposal (in September 1987 the Regional Waste Manager announced his intention to prohibit open burning of yard wastes effective April 1, 1988).

2.2.1 Combustion of Woodwaste in Wigwam Burners

The basic feature of a wigwam burner is simply to enclose an open fuel pile with a truncated metal cone and a screened top vent. The fuel charge is usually placed on a raised grate, and the combustion air is often supplied as underfire air blown into the chamber below the grate and as overfire air introduced through peripheral openings in the shell.

Over the years the major modifications to the basic system have been carried out, some of which include:

- structurally sound tight shell to minimize air leakage,

TABLE 1

Woodwaste Generation, Utilization and Incineration in the Mills in Williams Lake

Company	Woodwaste, m^3/year*		
	Generation	Utilization	Incineration
Lignum Ltd.	436 205 (100%)	67 980 (15.6%)	368 225 (84.4%)
Jacobson Bros. F.P. Ltd	481 525 (100%)		481 525 (100%)
Weldwood of Canada	538 175 (100%)	283 250 (52.6%)	254 925 (47.4%)
Pinette & Therrien Mills Ltd.	538 175 (100%)		538 175 (100%)
Khalsa Enterprises	39 655 (100%)		39 655 (100%)
Starline Cedar Mills Ltd.	169 950 (100%)		169 950 (100%)
West Fraser Timber Co.	283 250 (100%)		283 250 (100%)

* Bone Dry Volume

Based on the 1985 report of the Williams Lake Burner Committee of the millowners and managers.

- continuous feeding of fuel,
- forced air supply system,
- a damper located at the top of the burner,
- auxiliary fuel burner, and
- temperature sensors located near the top of the burner.

These features might not have been incorporated into all burners of recent designs. Some manufacturers, however, have introduced additional features such as controlled air supply, regulated fuel feed, hot gas recirculation and refractory lining of the burner, in an attempt to achieve the goal of clean burning.

The existing burners in Williams Lake were designed and built in the late sixties or early seventies. Although some modifications have been done to some of them since then, others lack the basic features of a good burner, as evident from Table 2. The state of some of these burners and the nature of emissions therefrom are best illustrated in Figures 5 to 7.

2.2.2 Emissions from Wigwam Burners

As with any other combustion system, the emissions from woodwaste incineration mostly result from incomplete combustion of the feed material. From wigwam burners the major emissions of concern are particulates and smoke. Particulates consist of varying quantities of ash and unburned wood particles. The unsightly

TABLE 2

Existing Woodwaste Burners in the Williams Lake Area

Burner Characteristics	Lignum Ltd.	Jacobson Bros. F.P. Ltd.	Weldwood of Canada	Pinette & Therrien Mills Ltd.		Khalsa Enterprises Ltd.	Starline Cedar Mills Ltd.	West Fraser Timber Co.
				Dimension Mill	Stud Mill			
Manufacturer	Applied Pollution	Scarf Steel	Lausman	Applied Pollution	Phelps	Scarf Steel	-	Interior Mill
Base Diameter, m	25.9	25.6	27.4	27.4	27.4	12.2	18.3	27.4
Height, m	27.4	31.7	27.4	27.4	27.4	12.2	18.3	27.4
Air Supply:								
Underfire	Yes	Yes	Yes	Yes	Yes	*	Yes	Yes
Overfire	Yes	Yes	Yes	Yes	Yes	*	Yes	Yes
Control of air supply and/or temperature	Yes	Yes	Yes	Yes	Yes	No	No	Yes
Auxiliary Fuel	No	No	No	No	No	No	No	No
Top Damper	Yes	Yes	No	No	No	No	No	Yes
Burner Temperature Sensor	Yes	Yes	Yes	Yes	Yes	No	No	Yes

* Air supply by natural draft only.

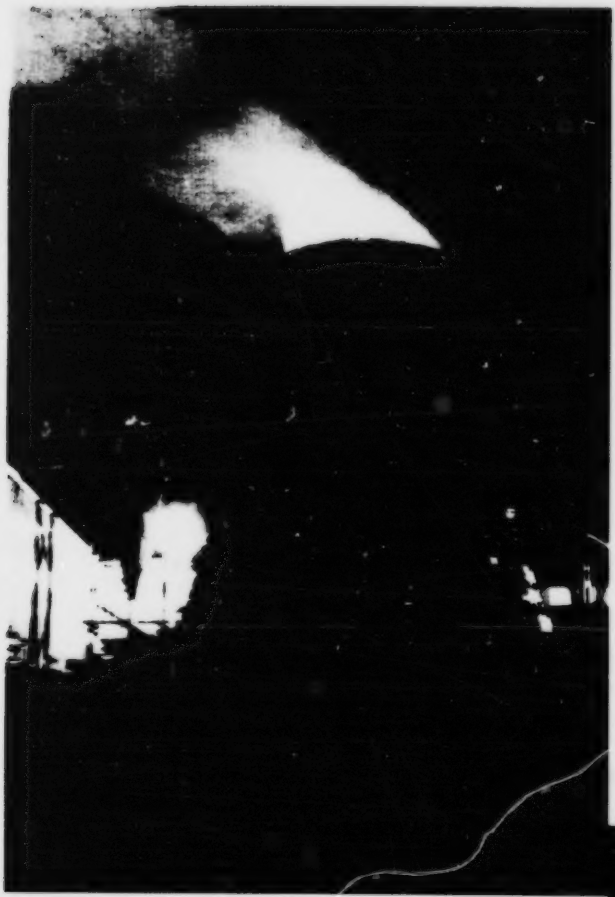
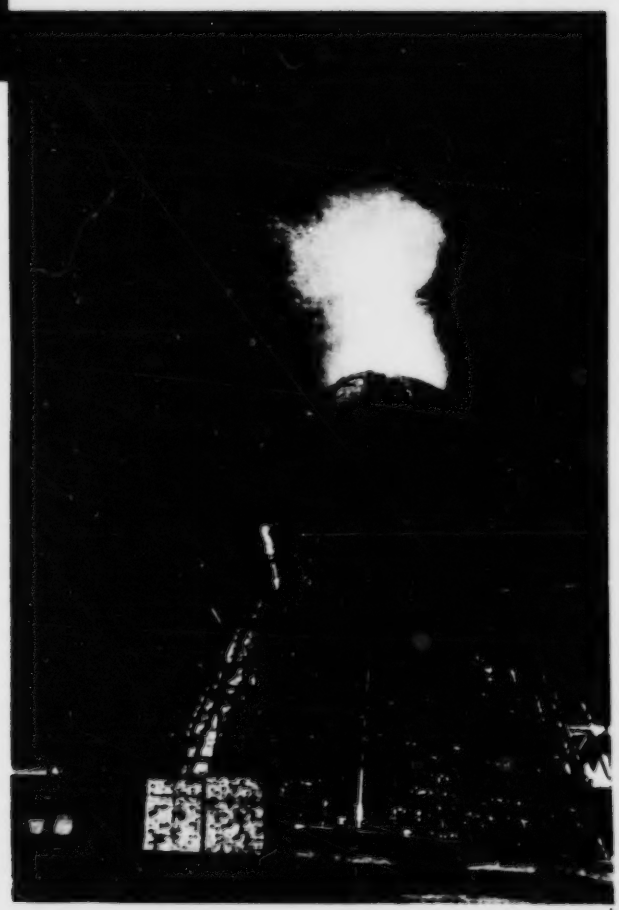


FIGURE 5:
Typical Emissions from
Wigwam Burners

JACOBSON BROS.
FOREST PRODUCTS



PINETTE & THERRIEN
STUDMILL BURNER

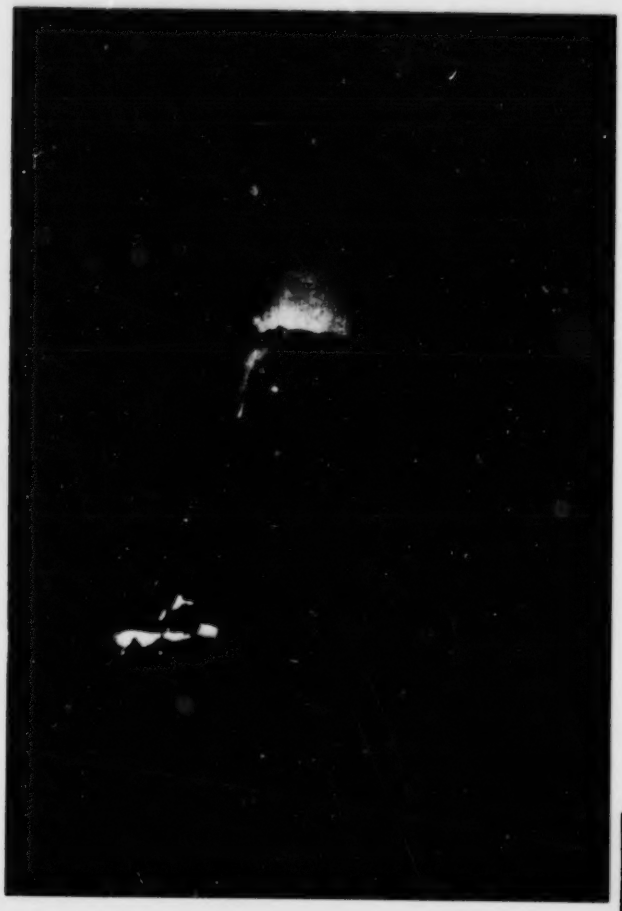
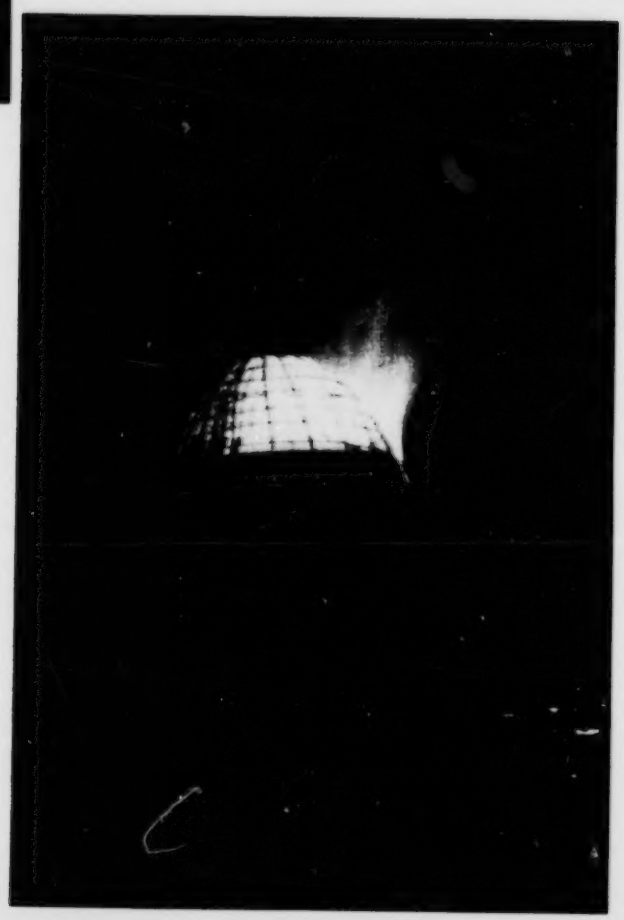


FIGURE 6:
Typical Emissions from
Wigwam Burners

KHALSA ENTERPRISES



LIGNUM LTD.

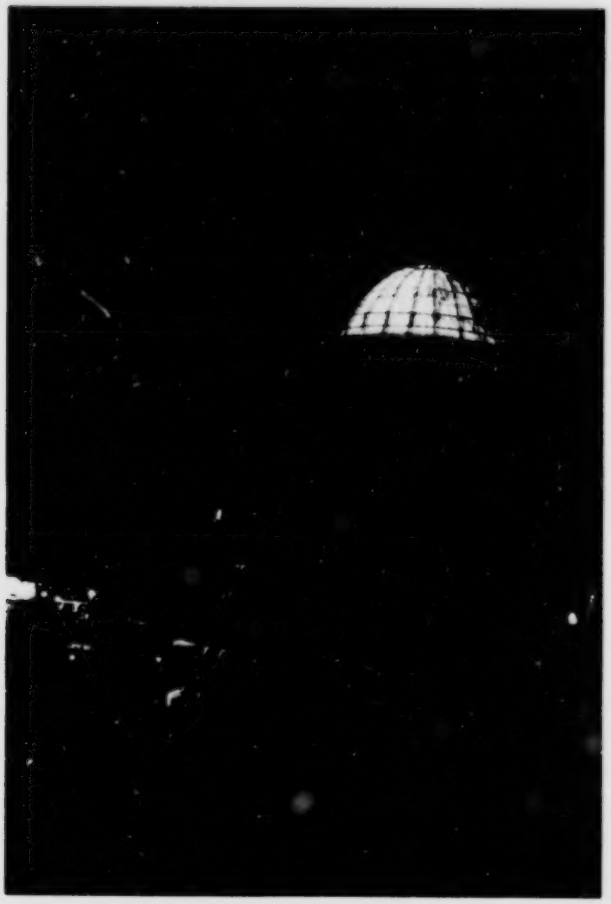


FIGURE 7:
Typical Emissions from
Wigwam Burners

WEST FRASER MILLS LTD.

WELDWOOD
MERRILL-WAGNER

emissions of smoke and blue haze are the hydrocarbons resulting from incomplete combustion of wood. Other gaseous contaminants of minor concern emitted are carbon monoxide, nitrogen oxides and sulphur dioxide. The latter is dependent on the sulphur content in the wood which is usually very small, and therefore, it is of not much concern in most instances.

The types and quantities of contaminants emitted from a wigwam burner are very specific to its design and operation. It is probably prudent to treat these burners as individual sources rather than to consider as identical sources. However, apart from the design there are certain common operational criteria which affect the emissions from wigwam burners:

- the composition and moisture content of the charged woodwaste,
- the burner size and the quantity of feed charged,
- the quantity of combustion air and the manner of its supply and control,
- the burner operating temperature, and
- the condition in which the burner is maintained.

Past investigations on the wigwam burner emissions have indicated that the emission characteristics vary widely depending on the operation and maintenance of the equipment. Based on those investigations the Environmental Protection Agency in the U.S.A. has developed emission factors for the major contaminants. Using these emission factors and the quantity of woodwaste incinerated, the estimated emission of

particulates from all burners could range from 205 to 4100 tonnes/year. It should be noted that these estimates are very crude and based on assumptions that all burners are operating either good or poor at the same time. The average emission rate of total hydrocarbons from the burners thus estimated is 2255 tonnes per year.

3.0 Disposal and Utilization of Woodwaste

The quantity of residues generated in the forest products industry in the Province far exceeds the amount that can be used as chips in the pulp and paper industry and as a raw material for other uses. It is a common practice to dispose of the excess woodwaste, although it is a potential source of energy and can be utilized in a variety of ways.

3.1 Disposal Methods

The common methods of woodwaste disposal are by landfilling and incineration. Small quantities are also used as materials for landscaping, soil conditioning, road bed, and animal bedding in farms. Landfills for woodwaste may pose problems of leachate generation, odour and spontaneous combustion, if they are not carried out properly and at wrong locations.

The primary purpose of incineration is to reduce the volume of woodwaste by combustion so that the small volume of ash residue can be handled and disposed of in

a relatively easy manner. The woodwaste is not so easy to burn in the type of incineration equipment commonly used. Often the emissions from the incinerators cause serious air pollution problems in the vicinity.

3.2 Utilization of Woodwaste

Many processing options are available for the conversion of wood to energy and chemical feedstocks. Generically both thermochemical and biochemical technologies are used in such conversion. These processes range in stage of development from laboratory scale to commercially proven ones. Since 1978 under the Canadian Bioenergy Programs a large number of studies have been carried out on the utilization of forest biomass in the country and some with particular reference to British Columbia scene. A partial list of available publications on various studies is appended to this report.

The most comprehensive study on the subject, "A Comparative Assessment of Forest Biomass Conversion to Energy Forms," ENFOR Project C-258 was completed in December 1983. This nine-volume report covers an excellent review of the proven and near-proven technologies for woodwaste utilization. Accordingly, no attempt has been made here to provide any detailed review of the available information on the potential technologies. Only pertinent information is summarized here to present a proper perspective of the situation.

3.2.1 Wood as Fuel

Wood and other vegetable matter are the parent materials of all natural solid fuels in the series:

Wood → Peat → Lignite → Sub-Bituminous Coal → Bituminous Coal → Anthracite

Wood consists essentially of cellulose, hemicellulose and lignin. The other constituents of wood are resins and other extractives, inorganic mineral matter, trace quantity of sulphur, and water both in bound and free forms.

The major properties which are commonly considered in characterizing wood as a fuel are:

- moisture content
- proximate analysis
- ultimate analysis
- heating value
- particle sizes

Other properties of wood, such as density, specific heat, angle of repose, flow behaviour and friction coefficient, are also important and considered during the detailed design of a wood utilization facility.

3.2.2 Properties of Woodwaste

In comparison to that of conventional fossil fuels, woodwaste has several undesirable characteristics which make it somewhat difficult to handle, store and burn or use otherwise:

- it is heterogenous, and lacks uniformity in wood species, in bark and wood proportion, in particle size, and in moisture content;

- high moisture content - difficult to support combustion above 55% by weight, "blackout" of boilers occurs beyond 60% which necessitates the use of an auxiliary fuel;

- it is bulky and requires large storage area;

- it deteriorates, packs and matts together in extended storage;

- it can ignite spontaneously in storage; and

- may create dust and odour problem during handling in dry summer.

However, it does have some very desirable characteristics too:

- it is relatively low in sulphur and ash content for a solid fuel;

- it is a clean fuel from air pollution aspects;

- it is available and inexpensive in areas where it is generated; and

- it has the potential ingredients for conversion to suitable forms of energy.

As the wood residue is generated from various unit

processes in the mill, some kind of preparation of the mixture usually becomes necessary prior to its utilization. Depending on the desired conversion technology of the woodwaste, such preparation may include dewatering, sizing and even thermal drying.

Typical characteristics of woodwaste available in the Williams Lake area can be described as follows:

Moisture content - 40%-50% by weight
Higher heating value - 18-20 MJ/kg
Sulphur - Trace - 0.1% by weight (dry)
Ash - less than 2% by weight (dry)

3.2.3 Conversion Technologies

The available conversion technologies and the potential application of their products are identified in Figure 8.

Direct Combustion - Combustion is an efficient method of utilizing the direct energy potential of woodwaste. There are several well established direct combustion processes for generation of steam and hot gases. The available equipment ranges from large industrial boilers to domestic woodstoves.

Pyrolysis - Pyrolysis or destructive distillation of a carbonaceous feedstock is a process whereby thermal decompositon of the material takes place in absence of oxygen. The products of pyrolysis of wood are charcoal, liquid distilates and fuel gas. The governing factors affecting the type and yield of the products are the

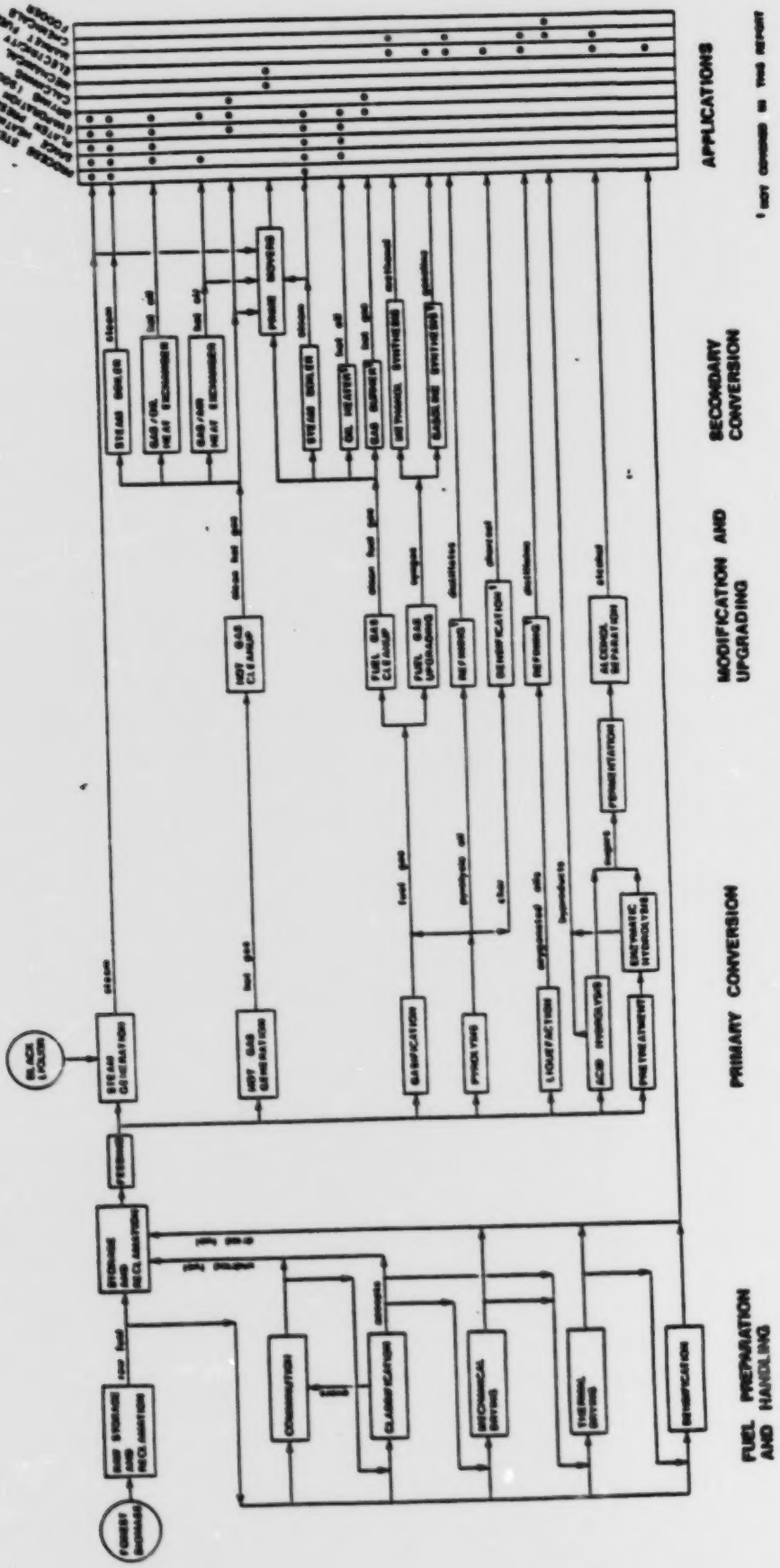


FIGURE 8: Schematics of Woodwaste Conversion Technologies.

SOURCE: ENFOR PROJECT C-258

reaction temperature, heating rate and residence time of the material in the reaction zone. Generally, high temperature, high heating rate, and long residence time favour gas production, while low temperatures result in increased char yield. The yield of liquid products is favoured at low temperatures and short residence times. There are several variations of the process for optimization of the product yield desired.

Gasification - Besides pyrolysis there are several other methods of woodwaste gasification which are based on the controlled use of air/oxygen, steam or hydrogen at elevated temperature and/or pressure. The technology of simple woodwaste gasification was developed as early as the 1850's. Vehicle mounted small wood gasifiers were introduced in several European countries during World War II to overcome the shortages of petroleum fuels for vehicles.

There are conventional processes for the production of low- and medium-energy gases. Several catalytic gasification processes using hydrogen are under development for the production of high-energy gas.

The product gases can be used directly or processed further for conversion to synthesis gases for the production of ammonia, methanol, organic chemicals, and substitute natural gas by well proven processes used extensively in related fields.

Liquefaction - In addition to pyrolysis and synthetic

gasification routes, there are a number of proven technologies for conversion of woodwaste to a variety of chemicals and liquid fuels. Prior to the advent of petrochemical and other synthetic sources, feedstocks for various bulk commodity and specialty chemicals were produced from wood. In generic terms these processes include thermochemical conversion such as solvolysis, extraction of wood chemicals by mechanical means and solvents, and biochemical conversion by hydrolysis and fermentation. The latter is used in the production of ethanol from wood.

In addition to liquid fuels, some of the chemicals which can be derived from wood are acetic acid, acetone, alcohols, carbohydrates, cellulosic and lignocellulosic derivatives, dyes, fatty acids, flavourings, furfurals, glycerol, oils, phenolics, resins, tar and waxes.

Densification - The woodwaste can be densified by several conventional processes to produce a fuel that is relatively clean, easy to handle and transport, and of consistent composition with less moisture and enhanced energy content per unit mass. Depending on the shape and size, densified woodwaste products are classified as logs, briquettes, cubes or pellets.

Despite the advantages there are two disadvantages with the densified products. The production process is relatively energy intensive, and the products are liable to disinterate upon contact with water. Although a process for water-stable product has been developed by British Columbia Research Council, it is not economically viable at present. There are two other

known products, Frajon Fuel and K-Wood, which are claimed to be moisture resistant; but the processes appear to be still in the demonstration stage.

3.2.4 Electricity Generation

The generation of electricity from wood fuel is a two-step process. The fuel is first converted to usable energy in a working fluid, which in turn is used directly or through a second working fluid in a prime mover, most commonly turbine or engine, to generate electricity. There are a number of power generating systems available; the proven and demonstrated technologies are illustrated in Figure 9.

The use of steam in turbines and engines has been the most common practice in power generation for a long time in both the utility and industrial sectors. These units are available commercially for all sizes.

Fuel gas fired internal combustion engines are also proven and commercially available for a limited range of sizes. However, the gas from the woodwaste gasifier must be cleaned thoroughly to reduce the levels of particulates and tarry mattes prior to its firing in the engine.

Gas turbines for direct firing with wood gas or indirect operation by clean, pressurized combustion gases are still in the various stages of development, although there has been some commercial application with other fossil fuels.

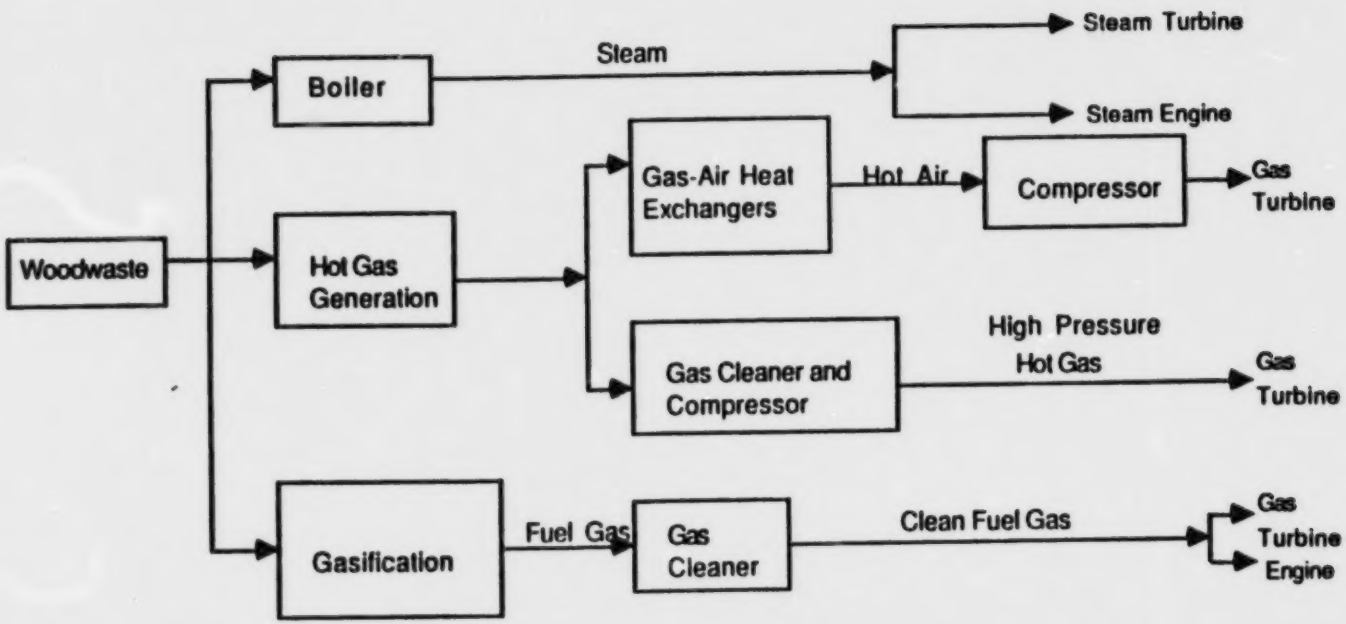


FIGURE 9: Schematics of Electricity Generation Techniques

Cogeneration - The term cogeneration is defined as the sequential production of electrical energy and useful thermal energy. The latter may be in a form such as hot exhaust gases, heat recovery through hot water, air or oil in a heat exchanger, or steam generation in a waste heat boiler. Common usages of thermal energy are as process steam, drying of materials, heating and air conditioning of buildings, heating of greenhouses, etc.

Depending upon the technical and economic considerations a cogeneration facility may be operated as a "base load" or a "load following" with respect to electricity generation and the sale of electricity to a utility. Generally these facilities can be classified as follows:

Topping Cycle - In this cycle electricity is generated by shaft work directly from the prime mover, and the useful thermal energy is extracted from the combustion unit's exhaust. A variation of this cycle is the dual fluid or Cheng cycle whereby any excess thermal energy is utilized to generate additional electricity during periods of low thermal energy demand.

Bottoming Cycle - In a bottoming cycle mode, the thermal energy is produced directly from a combustion unit, and the electricity is generated from the heat energy of the combustion unit's exhaust.

Combined Cycle - A combined cycle configuration is used to extract maximum available energy. Typically, it utilizes a gas turbine as the prime mover and the

electricity is produced by two different methods - shaft work and by use of the heat energy of the turbine exhaust gases to produce steam for additional electricity generation through a steam turbine. The combined cycle configuration is one of the latest and most efficient method of cogeneration.

3.3 Pollution Control Aspects of Woodwaste Disposal and Utilization Systems

The available information on the pollution control aspects of woodwaste disposal and alternative utilization methods has been reviewed and summerized below. As could be expected there are potential for multimedia discharges from the systems reviewed earlier. However, the characteristics of such discharges will depend on the particular system and the unit processes involved in the system.

Landfill - Woodwaste contains appreciable quantities of water soluble components that leach out on exposure to water. Depending on the species of wood from which the residue is generated, some leachate may be of acidic nature and also contain constituents which could affect the surface or ground water.

Also, in presence of adequate supply of moisture and air, the woodwaste in a landfill is decomposed by microbiological activities and oxidation reactions which may lead to:

- release of vapours and spores injurious to human

health; and

- spontaneous ignition of the material.

In dry areas, there may be problems with odour and fugitive dust in the surrounding area. The dust from certain types of woodwaste is known to be allergenic.

Proper site selection, landfill design and operation, and regular monitoring are essential for the reduction of potential hazards from woodwaste landfills.

Woodwaste Transportation, Storage and Handling - Depending on the system used to dispose of or utilize, the woodwaste may need to be transported, stored in outdoor piles and conveyed to the processing equipment. The potential discharges from these activities are:

- fugitive dust and odourous emissions from all three activities;

- leachate generation from outdoor storage piles; and

- the risk of spontaneous ignition of woodwaste in storage.

There are well proven control technologies to minimize discharges from these sources.

Woodwaste Preparation - The heterogenous residues generated at various sections of the mills often require dewatering and communition for the preparation of a

suitable mixture for the selected process. The potential discharges are:

- effluents from mechanical dewatering; and
- emissions of particulates from direct thermal drying and communition.

Again suitable control technolgies are available to reduce discharges of pollutants from all the above sources.

Incineration and Combustion - The basic process involved, thermochemical oxidation of woodwaste, in both these systems is the same, and the discharges therefrom would be similar although their actual characteristics would vary from system to system. As a fuel, woodwaste is generally considered as environmentally benign compared to other solid fuels and fuel oils. The potential discharges of major concern from woodwaste combustion have already been discussed in an earlier section.

With the exception of trench and wigwam burners for woodwaste incineration, the majority of the currently used large- and medium- scale combustion equipment are designed and operated to promote efficient combustion of woodwaste. As the emissions of unburned char, soot, hydrocarbons and carbon monoxide result from incomplete combustion, the discharge of these contaminants from the above systems is kept to a minimum and usually of not much concern. It is also a normal practice to install particulates control equipment to reduce its emission to

the acceptable level. There are several such control equipment of varying efficiencies used widely in the industry for small-scale combustion systems. However, cost considerations may limit particulates control equipment to multiclones only.

The design of the trench and wigwam burners for wood-waste incineration appears to be somewhat inadequate to provide conditions for efficient combustion of the material in a consistent manner. It is nearly impossible to incorporate any emission control device into a trench burner. As for the wigwam burner, because of its design retrofitting of any effective control system is reportedly cost prohibitive.

In recent years there has been some conern over the emissions of fine particulates and certain organic compounds from combustion sources. However, the information available on the emission of these contaminants from wood combustion systems is very limited at present.

There are two potential sources of major wastewater generation from a woodwaste combustion system:

- the effluent from the wet scrubber if such a device is used to control particulates; and

- the bottom ash and fly ash transport discharge effluents where wet systems are employed.

However, there are several conventional treatment

systems available for these types of effluents in the forest products as well as utility industries.

The major solid wastes generated in wood combustion systems are the bottom ash and fly ash, both of which are usually disposed of in landfills. In some instances where the fly ash contains reasonable amounts of unburned char, it is used as the feedstock for lamp black, carbon or charcoal production.

Steam and Electricity Generation - The sources and types of pollutants discharged from steam and/or electricity generation systems depend on the particular methods used. The conventional generation of steam in direct-fired boilers or in waste heat recovery boilers and that of steam-electricity are well established processes. The major discharges are various effluents and sludges from sources such as water treatment, boiler blowdown, cooling water system, boiler tube cleaning, etc., and their characteristics, treatment technologies, and disposal methods are proven.

When the electricity is generated in a gas turbine or engine by burning clean gas produced from woodwaste, the only discharges expected are emissions of flue gas and some cooling water streams. The flue gases from the gas turbine and engine will contain nitrogen oxides as the only contaminant of any potential concern. However, these devices of state-of-the-art design produce nitrogen oxides below acceptable levels.

Pyrolysis, Gasification and Liquifaction - With the exception of ethanol production from wood by biochemical

processes, all other systems in this group are based on thermochemical conversion of wood. Although not much information on the types and characteristics of discharges from these wood conversion processes is available, it is known that they are quite similar to that originating from thermochemical conversion of other biomass and coal. The major discharge streams from woodwaste conversion processes are:

- fugitive emissions of odourous and hydrocarbon-containing gases;
- process wastewater containing tars, oils, acids, and various other hydrocarbon condensates; and
- oily and biosludges

There are effective control technologies available to treat these multimedia waste streams to acceptable levels before their discharge to the receiving environment.

During biochemical conversion of wood to ethanol the major waste streams of concern are:

- wastewater streams containing hydrolysates, sugars, lignins, and still-bottom discharges; and
- various sludges and solids such as calcium sulphate, spent yeast or other enzymes, still-bottom sludges, dry lignin, and biodigester sludge.

While several of these streams could be processed further for by-products recovery or used at the facility, the others should be treated prior to discharge. The technologies for necessary treatment of

those waste streams are well established and readily available.

Densification - Apart from the sources such as woodwaste storage pile, handling and preparation, and steam boiler, the only sources of discharge of any major concern are the pellet cooler and pellet handling system. There is a potential for particulates emission from these two sources; however, there are control devices which are efficient and readily available.

Besides the above process-specific sources of pollutant discharge discussed above, any industrial facility will also have certain common sources of minor discharges. These include sanitary effluent, yard and building drainage, auxiliary boiler and/or power generator, etc.

4.0 Woodwaste Burner Emission Regulations in British Columbia and Several Other Jurisdictions

In British Columbia the emissions from woodwaste burners are regulated by permits generally based on "Pollution Control Objectives for the Forest Products Industry of British Columbia, 1977." The recommended objectives for emissions from woodwaste burners stipulate limits on the opacity of the emissions only. The monitoring requirements for the permits include recording of the burner gas temperature and establishment of a correlation between the temperature and opacity. Waste Management Permits also limit the total dustfall in the plant vicinity.

Regulations on the disposal of woodwaste in wigwam or conical burners in several other jurisdictions have been reviewed. Any aspects of these regulations which are different from that of British Columbia are outlined below.

Alberta - The burner is required to be operated at a minimum temperature of 425°C excluding the start-up period. The operator is required to submit a comprehensive monthly report on the burner performance and production data. The performance data for each day must include the minimum daily temperature of the burner during its operation, excluding the start-up period, and an explanation for any excursion of temperature below 425°C for more than one-third of the operating time.

Ontario - The burning of woodwaste must be controlled, and the design and operation of such facilities must comply with the approved guidelines. Emissions from a burner must also meet the point of impingement criteria for particulates as well as the opacity limits. There has not been any permit application for a woodwaste burner for a long time, and it is unlikely that wigwam burners will be approved any more without any control equipment.

U.S.A. - In the U.S.A. emission sources are regulated by the local, state and federal agencies. The federal Environmental Protection Agency generally issues permits for large emission sources, but in sensitive areas with air quality non-attainment problems its approval is also required for small emission sources. The state and local

agencies regulate all sources of emissions, and under certain circumstances the local agencies may stipulate more stringent emission limits than that required by the state.

California - According to the officials of the California Air Resources Board, the present policies and emission standards discourage burning of woodwaste in woodwaste incinerators. The Board has not dealt with any permit application for such facilities since the late sixties.

Washington - Under the current regulations in the State of Washington, all wigwam burners must meet all provisions of general standards for maximum emissions, minimum emission standards for combustion and incineration units, and minimum standards for wigwam burners. Basicially these standards require all wigwam burners to use reasonably available control technology, and in environmentally sensitive areas the best available control technology must be installed.

Montana - In the State of Montana, construction and operation of woodwaste burners must meet certain requirements. The opacity of emissions is limited to 20%, averaged over any six consecutive minutes. The maximum particulates emission allowed is 230 mg/m^3 corrected to 12% CO_2. It is also necessary for the burner operators to maintain a daily written log of the burner operating parameters and atmospheric conditions.

Tennessee - In the State of Tennessee, any wigwam burner having an exhaust flow rate of 2,833m^3 or more is

required to be equipped with continuously recording equivalent opacity monitor, if the opacity of emissions exceed 20% at any time of operation.

Oregon - The Administrate Rules of the Department of Environmental Quality stipulate the following:

- No operation of any type of wigwam burner is authorized in areas within incorporated cities having a population of 4,000 or more and within 4.8 km of the corporate limits of any such city. Similar restrictions to the operation of wigwam burners apply in areas designated as special control areas with respect to air quality.

- No approval to modify a wigwam burner or to install a modified wigwam burner is granted unless it is demonstrated to the Department that;

- no feasible alternative to incineration of woodwaste exists; and
- the burner is to be constructed and operated in accordance with the prescribed design criteria.

Any authorized facility must comply with the stipulated requirements for the burner operation, emissions and monitoring.

Sweden - The woodwaste from sawmills is considered as a fuel, and burning without energy recovery is allowed only under special circumstances. New emission guidelines for particulates and nitrogen oxides from

combustion facilities will virtually prohibit operation of a wigwam burner without any emission control equipment.

4.1 Regulations and Policy on Energy Recovery and Electricity Generation from Wastes

The success of waste utilization for energy recovery hinges on both environmental and energy regulations, particularly with respect to electricity generation. The viability of any cogeneration or parallel generation project depends on the policies of the electric utilities.

In the following the pertinent regulations and policies in several jurisdictions are summarized.

British Columbia - In British Columbia under Section 8(1)(f) of the Waste Management Act, 1982, a manager may "require the permittee ro recycle certain wastes, and to recover certain reusable resources, including energy potential from wastes."

At present British Columbia Hydro and Power Authority (BCHPA) purchases small quantities of power from three private producers. These purchases began in the late 1970's when in anticipation of power deficit private producers were encouraged by BCHPA.

Currently BCHPA has the following policies on the purchase of electricity from other producers.

Purchases within the Integrated System - BCHPA will not purchase electricity from suppliers during periods of surplus generation within the integrated system, except in special circumstances. Where it purchases power from private producers under those circumstances, it is subject to the condition that BCHPA may curtail or interrupt deliveries if the system moves into a surplus. The purchase is also subject to other conditions set out in the agreement between the producer and BCHPA.

The rate which will be paid to such a producer by BCHPA is equivalent to the trailing step of the prevailing price purchased from BCHPA. There are different rates of electricity charged by BCHPA according to the customer classification - residential, commercial and industrial. For each class of user, BCHPA charges on the basis of block rates with the rates decreasing as power consumption increases beyond pre-specified levels. The trailing step is the lowest block rate paid by a customer.

Purchase in Non-Integrated Areas - In areas outside the integrated grid system BCHPA will consider purchase of electricity from other suppliers that would displace power production from BCHPA's diesel generation systems. The unit price BCHPA would pay for such power is the average of the cost of the supplier and BCHPA's cost of diesel power generation. However, the upper limit on the unit price paid by BCHPA would be 90% of its marginal cost of diesel power generation.

In the event of an area being integrated into the grid earlier than originally planned, the unit price paid to

a supplier would revert to a rate paid by BCHPA to a supplier on the integrated system.

Other Provinces - Most utilities in other Provinces, except in Nova Scotia and Ontario, have reportedly no formal buy-back policy on the purchase of electricity from small producers. However, some utilities may come to an agreement with suppliers on an ad-hoc basis.

The Nova Scotia Power Corporation has established a tarrif structure for the purchase of electricity from other producers. The general method used by the Corporation is to set a price which would reflect the contribution of any purchased power into the system energy demand.

The Province of Ontario has recently adopted three strategic goals with respect to energy:

- reducing dependency on imported fossil fuels;
- postponing the need for large-scale, central power generation plants; and
- attaining a more balanced and diversified electricity system.

The objectives of the government are to improve efficiency of energy use and deliver electricity at a reasonable price. To attain these objectives the government has taken a number of steps, the major ones include:

- directing Ontario Hydro to support the generation of electricity by private producers;

- assessment of the potential use of indigenous renewable resources for cogeneration in an environmentally acceptable manner;
- providing assistance in evaluation of projects, site selection and environmental impact assessment; and
- financial assistance in some cases.

Consequently, in January 1985 a new pricing system was implemented by Ontario Hydro for purchasing electricity from other generators. The system is based on the avoided cost of future power generation by Ontario Hydro.

U.S.A. - The recent development of resource recovery and cogeneration facilities in the U.S.A. has been assisted by several federal and state regulatory activities. In the federal domain, on the one hand the Power plant and Industrial Fuel use act and the Public Utilities Regulatory Policies Act (PURPA) have encouraged electricity generation by small producers, on the other hand, the Environmental Protection Agency has been playing a supplementary role in such developments by promoting resource utilization and emission offsets, emission credits, etc. PURPA has provided the economic incentives in the form of accelerated depreciation and investment tax credits to the project developers. Under this Act, the utilities are required to purchase electricity from paralled generators on the basis of their long-term "avoided cost" of power generation. However, PURPA leaves it to the individual States to define the "avoided cost", which has reported to have resulted in some controversy and litigation in some jurisdictions.

California - The State of California has been providing additional incentives to small power producers through California Alternative Energy Source Financing Authority in the form of certified tax-exempt bonds.

California Air Resources Board and California Air Pollution Control Officers Association, in co-operation with Environmental Protection Agency, have developed a protocol for determining the magnitude of emission credits available to facilities which burn biomass to generate steam or electricity, pursuant to the California Health and Safety Code. These emission credits are based on the air pollutant incremental emissions benefit which would result from displaced open burning of forest residues or agricultural burning.

Oregon - In March 1972 the Environmental Quality Commission of the State of Oregon declared a policy with respect to disposal of woodwaste in wigwam burners. It was noted then that the technological and economic development had enhanced the degree to which woodwaste residues could be utilized or disposed of in ways not damaging to the environment. However, recognizing that complete utilization of woodwaste is not presently possible in all parts of the State, because of geographical and economic conditions, the general policy of the Commission has been to:

- encourage complete utilization of woodwaste;
- phase out, wherever reasonably practicable, all disposal of woodwaste by incineration; and
- require approved modifications to any remaining wigwam burners.

5.0 Options Considered for Woodwaste Disposal and Utilization

As evident from Section 3 there are a number of options available for the disposal and/or utilization of the surplus woodwaste. However, within the scope of this study it has only been possible to consider a selected number of alternatives. No up-to-date detailed study on the cost of these options has been carried out. Instead the information from similar studies carried out earlier for Williams Lake and other areas of the Province have been reviewed and updated wherever possible.

The available alternatives discussed below are categorized as near-term and long-term options. Prior to the asssessment of these options, it is considered appropriate to review the woodwaste availability in the area for a proper perspective of the situation.

5.1 Woodwaste Availability

Excluding the quantity of chips production for use outside the area, the total volume of woodwaste generated in 1985 was about 2.5×10^6 m^3 (bone dry), based on a rate of 602 kg per MFBM of lumber produced. Of this quantity about 0.35×10^6 m^3/year is used for energy recovery in the mills, and the surplus which is presently incinerated is available for alternative uses.

There are several factors which affect the generation of woodwaste and thus the availability of surplus varies periodically. The major factors are:

- log consumption and lumber production which depend on the availability and price of timber as well as the demand and price for the lumber;
- demand for chips in the pulp and paper industry;
- technological changes in both sawmills and pulp production; and
- other factors such as severe weather conditions, fire, strikes, etc.

According to the Ministry of Forests and Lands, the present annual allowable cut on Crown land within the Williams Lake timber supply area is 3.75×10^6 m^3, This volume includes approximately 1.25×10^6 m^3 of salvagable timber damaged by the mountain pine beetle epidemic. It is, however, expected that the long-term yield would remain above 2.5×10^6 m^3. An unspecified volume of private timber is also harvested in the area. The Ministry does not foresee any reduction in the rate of harvesting for a reasonable time frame; however, the annual allowable cut is reviewed periodically. There is a potential of increased harvesting if in the future technology allows greater utilization of small diameter timber stands.

In view of the above the woodwaste volume of 2.14×10^6 m^3 (bone dry) incinerated, according to the estimate by the industry in 1985, is considered as the surplus available at present. An update of the hogfuel availability in the interior of the Province is being currently prepared under a contract from the Canadian Forestry Service, and it is expected to be available at the end of this year.

Energy Value of the Available Woodwaste - The available annual surplus woodwaste of 2.14 x 10^6 m^3 is roughly equivalent to 0.4 x 10^6 tonnes/year of bone dry material. Assuming a higher heating value of 20 MJ/kg, the total available heat from this surplus woodwaste is estimated to be 8.2 PJ/year. As there is always some energy penalty involved during conversion of the available heat to useful heat, the actual usable energy would depend on how the fuel is processed. The estimated fuel requirements for equivalent energy output by combustion of woodwaste and other common fuels are shown in Table 3.

5.2 Near-Term Options

In view of the nature of the existing problem the following options outlined here are based primarily on environmental considerations. However, because of the complexity of the situation involving seven facilities and eight wigwam burners at varying stages of deterioration, it does not appear that there is any single realistic solution. To reduce the levels of excessive emissions from the burners a combination of the following options and any other innovative measures would be necessary to produce the desired results.

1. Compliance with Permits

The most effective and immediate course of action obviously is to enforce the Waste Management Permit conditions for operation of these burners. This may mean shutting down of several burners, which could result in huge stockpiling of woodwaste in those plants and ultimate closure of operations.

TABLE 3

Fuel Requirement for Equivalent Energy Output
(For Combustion Purposes)

Fuel	Unit	Higher Heating Value GJ/unit	Conversion Efficiency %	Fuel Requirement For 1 GJ
Natural Gas	$1000m^3$	37.4	76	$35.2m^3$
Light Fuel Oil	m^3	38.7	80	$0.032m^3$
Heavy Fuel Oil	m^3	41.7	80	$0.029m^3$
Woodwaste [1]	t	11.6	60	0.148t
Electricity [2]	1 GJ is equivalent to 0.278 MWh			

1. Assumed a mixture of typical hog fuel in the interior of the Province, moisture content 50%

2. Based on the average conversion efficiency of electricity generation from thermal power sources. It is also generally assumed that 3.6 GJ of secondary electrical energy is equivalent to 10.5 GJ of primary hydroelectric energy.

2. Repairing of Existing Burners

The existing burners could be repaired and modified as necessary to burn woodwaste in an efficient manner. The extent of repairs and modifications necessary would depend on the conditions of each burner.

As the most important factor which influences the emissions from wigwam burners is the maintenance of a relatively high combustion temperature, upgrading of any of the existing burners must be carried out with that particular objective.

To achieve that objective the following must be considered as essential:

(i) The recognized optimum operation regime for the exit gas temperature is in the range of 370°-480°C.

(ii) The burner should be operated at the designed fuel rate. It is difficult to maintain the optimum temperature if the burner is oversized or undersized.

(iii) Woodwaste should be fed into the burner through a enclosed chute with the material entering just above the burning fuel pile. It must be fed at a relatively uniform rate, preferably via a storage bin with a meter.

To avoid entrainment of fine fuel particles in the exit gas, any firing of shavings and sawdust should be made in a controlled manner. Such

materials could be introduced in small quantities at the bottom of the burner and preferably when the unit is operating well under a steady state.

(iv) Air supply to the burner should be controlled in such a manner that the underfire air supply system is capable of providing up to about 50% of the theoretical combustion air necessary for the woodwaste feed rate. The underfire air should be supplied uniformly through different zones of the fuel pile, and be regulated as required.

A forced overfire air supply system should be designed to provide adequate velocity and to maintain the necessary turbulence in the burning fuel pile without excessive entrainment of particulates in the flue gas. The amount of overfire air should be measurable as well as controllable, and the system should be designed to supply up to about 200% of the theoretical combustion air necessary.

(v) The burner should have all cracks and openings eliminated as much as practical to prevent fugitive air entering the combustion system, and thus diluting the controlled air supply.

(vi) A properly designed automatic damper at the top of the burner must be installed to prevent air leakage and to maintain high temperature conditions inside.

(vii) A continuous temperature monitoring and recording system for the burner exit gas must be provided. Automatic control of fuel and air supplies modulated by the exit gas temperature is a preferred system as it reduces supervision required to maintain adequate burning conditions.

(viii) Auxiliary fuel burners must be installed and operated during the start-up. These burners should also be used when woodwaste containing high moisture is fed into the wigwam burner.

In addition to the above requirements, there are other measures specific to each burner which could be implemented for its optimum operation. Besides these steps the plant management and operating personnel must pay a continuous interest and attention to the operation of the burner.

However, it should be recognized that there are certain inherent deficiencies in the basic design of the wigwam burner which preclude it from being an effective combustion system for woodwaste. It is doubtful whether even a well designed and operated unit, without any control device, can be operated in a consistent manner with emission characteristics of 20% opacity and particulates concentration of 230 mg/m^3 (corrected to 12% CO_2). These emission characteristics are considered in most instances as the minimum necessary for sources with low effective heights of emission to prevent adverse impacts on the air quality.

The design of the wigwam burner makes it difficult to be fitted with an emission control equipment. There were some attempts in the 1960s in the U.S.A. to control particulates emission by installing wet caps, wet scrubbers, and even in one case an electrostatic precipitator. There were operational problems and the costs were reportedly prohibitive.

No estimates on the cost of necessary repairs and modifications to the existing burners have been made. However, considering the state of the existing burners such costs are expected to be quite high.

3. Reduction in Number of Burners

There are several burners which lack the essential features of a modified woodwaste burner, and must be shut down as these are most likely beyond repair and modifications. The woodwaste from the mills thus affected could be incinerated either in the remaining burners at other mills after necessary repairs and modifications or in a new centralized incinerator as outlined later. To accommodate the additional woodwaste from the displaced burners, the existing ones could be operated continuously. The emissions from a well maintained continuously operated burner are lower than that from batch operated units. The total cost for operation of the reduced number of burners can be shared among the parties involved.

4. New Centralized Burner

The Burner Committee of the mills in the area conducted

a study for centralized burning facilities. It was estimated that three 27.4m diameter modified wigwam burners would be required to dispose of 2.15×10^6 m^3 of bone dry woodwaste by operating continuously. The capital cost was estimated to be $5.6 million, and the annual operating cost was estimated to be $3.3 million.

It should be noted that the above estimates of capital cost included $600,000 for hogging, handling and loading facilities for each mill, although this particular cost was estimated for one mill only. It is quite likely that this cost could vary with each mill depending on existing situations therein. Similarly no details about the trucking costs for each mill were provided.

Moreover, any final balance sheet must also take into account the current operating costs of the existing eight burners in seven mills.

As an alternative, enquiries into the possibility of installing silo type refractory burners have indicated that the capital cost for burners would be higher than wigwam burners. One supplier has indicated that the cost of a 50t/h capacity burner delivered and installed would be $316,750 (U.S.) plus tax and duty. It does not include foundation, conveyor for fuel, and electrical connection costs. Two such burners will be necessary for the surplus woodwaste. Although the cost of the burners is higher, no hogging of the woodwaste is required according to the supplier.

The silo burners can be fitted with wet scrubbers or rock towers for particulates control, and waste heat can be recovered as hot air, oil, water or steam by using suitable heat recovery systems at additional costs.

5. Utilization of Woodwaste in the Mills

There is a good potential for utilization of a significant quantity of woodwaste at individual mills to produce heat for the lumber dry kilns. As mentioned before, only 14% of the total woodwaste is utilized in only two mills to produce a part of the heat necessary for the drying of products. Both natural gas and electricity are used to satisfy the remainder of the energy needs at these plants.

The mills should be encouraged to utilize their own woodwaste to meet at least their thermal energy needs for lumber drying, space heating and hot water supply. The normal consumption of natural gas in drying kilns in the Interior mills is reported to be about 1.5 GJ per MFBM of lumber. Based on the lumber production of 722,581 MFBM per year, the total energy supplied via natural gas is about 1.14 PJ per year for lumber drying alone. Although a steam heated lumber dry kiln has a thermal efficiency of about 60% compared with 40% for a gas fired one, the cheap price of natural gas discourages the use of woodwaste to generate steam.

Hence, any additional use of woodwaste for useful purposes at every mill will reduce the quantity of

surplus material for disposal. Packaged boilers for steam generation, combustors for hot gas generation, and heat exchangers are readily available. The emissions from these units are easily controllable by available devices, which are in most cases supplied as an integral part of the combustion unit. Particulates emission level from these units is considerably less than that from wigwam burners.

5.2.1 Impact on Particulates Emission

The emission of particulates from a given combustion system is largely proportional to the quantity of woodwaste burned and the extent of controls applied both inside and outside the combustion system. In the case of a wigwam burner the emission rate of particulates varies from 0.5 to 10 kg per tonne of woodwaste incinerated depending on the burner operation. Whereas because of the improved combustion conditions used, the particulates emission rate is significantly less from silo burners, combustors and boilers. Moreover, further reduction can be achieved by adding particulates control equipment to these systems. For example, the particulates emission from a boiler equipped with two multiclones can be reduced to 0.36 kg/t, and electrostatic precipitator or fabric filter to 0.07 kg/t of woodwaste burned.

Therefore, the major objectives of the options discussed above are: (i) to reduce the quantity of woodwaste to be burned, (ii) to burn it well, and (iii) to recover the energy from woodwaste wherever practical.

5.3 Long-Term Options

Although from technological standpoint any of the wood-waste utilization processes discussed earlier could be regarded as a potential choice for the Williams Lake area, only two of them, namely wood pelletization and generation of steam and electricity, are considered below.

The primary reason for such a limited choice is the lack of information necessary for any meaningful analysis of the other potential utilization methods. Financial analysis of the two options are based on previous studies carried out by others on the utilization of woodwaste in the Province.

1. Generation of Electricity

There is no recent comprehensive report on the power generation feasibility from woodwaste in Williams Lake. Two such studies were carried out in 1978-1979 for the Quesnel area where the surplus hog fuel disposal was a problem. Although the situations in Quesnel and Williams Lake are not identical, there are similarities with respect to woodwaste quality and volume. These two studies have been reviewed primarily for financial analysis.

The above studies were carried out by H.A. Simons Ltd. in 1978 and by Sandwell & Co. in 1979 for the feasibility of both a single purpose electric utility plant and a cogeneration facility with the steam used in lumber dry kilns. Both studies assumed the same volume of hog fuel availability of approximately

2×10^6 m^3 (as fired) and similar boiler-turbine designs. However, there were differences in several other assumptions on the cost of hogging and transporting the fuel, actual steam generating conditions, plant operating period, and emission control equipment. Consequently, the studies produced significantly different cost estimates.

Plant Design and Emission Control Systems - Both studies assumed the plant operator would pay the sawmill the cost of hogging and bear the cost of transporting the hog fuel. H.A. Simons Ltd. used \$0.18/m^3 as the cost of hogging and the transport cost to vary depending upon which of the four sites was selected. Sandwell & Co. used a hog fuel cost of \$0.14/m^3 and a transportation cost of \$0.31/m^3.

H.A. Simons Ltd. considered four different examples of turbine/generators with the following characteristics: (a) 2859 kPa/357°C; (b) 4238 kPa/374°C; (c) 6307 kPa/440°C; (d) 8375 kPa/482°C. The hog fuel boiler efficiency was 67.5%. The plant was assumed to operate 8,400 hours/year. The lumber kiln heat was determined from the existing natural gas consumption. The steam required for kiln heating was 24,516 kg/h. Given these assumptions, the effective capacity of the four alternative designs was 41.5 to 49.5 MW without kiln heating and 37.6 to 45.5 MW with kiln heating.

Sandwell & Co. examined a plant design that would deliver steam to the turbine at 8720 kPa and 510°C. The boiler was designed to accept municipal solid

waste as supplementary fuel and permit future conversion to coal. The plant was assumed to operate 8,000 hours/year. They also considered the alternative of displacing natural gas as fuel for heating kilns. The rated capacity of the plant under the given assumptions was 60 MW.

H.A. Simons Ltd. assumed that the dust collection system would be a two-stage mechanical cyclone collector. Sandwell & Co. examined the costs of using electrostatic precipitators to control air emissions.

Capital Costs - Neither study provides a detailed breakdown of their capital costs, so it is difficult to determine what causes the large difference in costs. Both studies appear to include in capital the costs of: site purchase and preparation; structures and equipment; of providing kiln heating; engineering and contingency; interest charges and working capital.

H.A. Simons Ltd. based their capital costs on the assumptions that the plant would be operated as a utility with favourable financing, a low required rate of return and an economic life of 30 years. Given these assumptions, the capital costs ranged from $62.5 to $69.4 million (1986 dollars) depending upon the design.

One of the scenarios considered by Sandwell & Co. was that the plant would be industry owned and operated and privately financed. The analysis considers the

plant return over a twenty year time period. The capital costs of the plant given these assumptions is estimated to be 105.4 million (1986 dollars).

Operating Costs - These include: wages and salaries; costs of transporting hogged fuel and ash; equipment, supplies and services; insurance and taxes; plant overhead and a contingency.

The estimate of the annual operating costs by H.A. Simons Ltd. range from 2.8 to 3.3 million (1986 dollars) depending upon the site, whereas that by Sandwell & Co. indicates it to be 7.5 million (1986 dollars).

Financial Returns - The key assumptions made by H.A. Simons Ltd. in calculating the financial returns are that steam is sold to the mills at a price equivalent to their present yearly natural gas cost. The utility undertaking the project would require a rate of return of 9% and receive a depreciation rate of 3.3% on a straight line basis over 30 years. The utility would not be subject to income tax on its revenue from steam and electricity sales. In order to satisfy these conditions, the price that would have to be received for electricity generated would be (a) $0.028 to 0.032 (1986 dollars) without kiln heating and (b) $0.026 to 0.028 (1986 dollars) with kiln heating.

Sandwell & Co. looks at the return over the shorter time period of 20 years. In order for a private operator to obtain an internal rate of return of about 12%, it would be necessary to receive a price

of about $0.040 to $0.043 per kwh. of electricity generated.

Comments - It would appear that many of the costs in the H.A. Simons Ltd. study are under-estimated. Also, the example of a plant owned and operated as a utility with a low cost of financing, low required rate of return and no income tax payments reduces the value of the study for present purpose.

The Sandwell & Co. study probably gives a more realistic estimate of the price that would have to be received for electricity produced in order to make a cogeneration project feasible. The internal rate of return of 12% probably represents a minimum acceptable rate so that a price of 4.5¢ to 5.0¢ per kwh. would appear to be required.

Other Studies - Recently two other estimates have been done for the Ministry and for Lignum Ltd. specifically for Williams Lake area and for electricity generation only. The estimate for the Ministry has been carried out by H.A. Simons Ltd. and that for Lignum Ltd. by Centurion Technology Inc. None of these are done in any detail, so the electricity generation costs are crude estimates only.

H.A. Simons Ltd. has estimated that the total wood-waste (bone dry) volume of 2.14×10^6 m^3/year available from all mills in Williams Lake would produce 60 MW of electricity. The quantity of wood-waste available from five mills located on the northern end of the city would support a 36 MW plant. Based on an assumption of 20-year amortization period,

the estimated costs are:

- for a 60 MW plant the total cost would be $72 million and the electricity cost in the range of $0.024 - 0.033/kwh; and
- for a 36 MW plant the total cost would be $54 million and the electricity cost in the range of $0.030 - 0.038/kwh.

In both cases the operating and maintenance costs are assumed to be 6% of the capital costs. The ranges of electricity costs reflect the costs for woodwaste assumed - the low rate corresponds to free hog fuel and the high rate allows about $1.73/$m^3$ of woodwaste to cover transportation costs.

The study by Centurion Technology Inc. indicates that based on a surplus woodwaste (bone dry) of 0.48×10^6 m^3/year at the Lignum Ltd. facility, a 15 MW plant is feasible at a capital cost of about $20 million and operating and maintenance costs of $1.2 million a year. The cost of electricity is estimated to be $0.045/kwh for a pay-back period of 8 years.

General Comments - The above studies indicate that there is a good potential for electricity generation from the surplus woodwaste in Williams Lake provided:

- there is an assured supply of hogfuel on a long-term basis;
- the excess electricity can be sold to BCHPA; and
- a reasonable rate of return for the substantial capital investment by any investor.

These prerequisites apply to both types of facilities, single purpose electricity generation plant and a cogeneration plant for utilization of electricity as well as steam, and are discussed in a later section dealing with constraints.

From perspective of an overall energy recovery potential, a cogeneration facility appears to be more attractive. The energy efficiency of conversion of woodwaste to electricity is in the range of 20 to 30%, whereas the overall energy efficiency can be increased to 80-85% by proper utilization of the heat available from the steam otherwise wasted. In Williams Lake the prospects for steam utilization appear to be good, as the majority of the lumber produced in the mills is dried in natural gas fired dry kilns. Other commercial and institutional applications of steam may also be found in the area to increase revenue from steam sales and thus to offset the operating cost of the facility.

The utilization of woodwaste for steam-electricity generation has been a long standing practice where it is available readily and the cost of conventional fossil fuels are high. Such uses in the Scandinavian countries are well recognized for years. In the U.S.A. the utilization of woodwaste and other biomass for power generation has been increasing in recent years due to both economic and environmental reasons, as various incentives are being given by the authorities for such usages. For example, at present in California there are 36 biomass-to-energy plants in operation, 6 more under construction, and another

10 are in the planning stage. The capacities of these plants range from 1 MW to 55 MW. There are presently six such plants operating in the State of Oregon.

Recently in Ontario a 7 MW facility has started operating at a sawmill near Chapleau to utilize the woodwaste generated in three nearby mills. The woodwaste used to be disposed of in wigwam burners which caused an air pollution problem in the area. One more such plant is under construction in Ontario, and at least another two have reached the planning stage.

It is also worth mentioning that a classic example of a successful facility has been operating in Eugene, Oregon since the 1940s. The Eugene Water and Electricity Board (EWEB), a city-owned utility company, has been generating steam and electricity from woodwaste in the heart of downtown Eugene. The experience of EWEB has demonstrated that woodwaste can be utilized in a manner that is not detrimental to the environment. A total of 33.8 MW of electricity and 272,400 kg/h of steam is generated from woodwaste generated at the nearby sawmills.

It has been estimated that the EWEB facility is responsible for eliminating at least 25 wigwam burners in the Eugene area while emitting less than 1/25th of the quantity of particulates to the atmosphere. The quality of emissions from the boilers is within the acceptable levels of the local, state and federal regulations.

Besides supplementing its electrical need, EWEB provides steam service within specified areas of the Eugene business district and to several customers nearby including:

- a university campus,
- a large hospital,
- a large cannery, and
- a commercial greenhouse complex about 8 km away.

It has been demonstrated by EWEB that under special circumstances, even with 20-to 30-year old equipment woodwaste can be used for electricity generation and district heating in an economically viable way in competition with the relatively low priced hydro-electric power. EWEB has never required tax support, but has contributed over $7.5 million (U.S.) "in lieu of taxes" to three local municipalities and school districts in 1986. Since its inception the total such contribution has amounted to over $74 million (U.S.)

Pollution Control Aspects - From pollution control aspects it appears that these facilities can be equipped with best available control devices to minimize emissions not only of particulates but also of nitrogen oxides and sulphur dioxide, if it is required, and still be economically viable, even for plants of 8-26 MW size.

Conventional treatment technologies are applied to wastewater streams prior to their discharge. Solid wastes consist mainly of boiler ash and are usually

disposed of in landfills. However, in some cases the fly ash is used in the production of charcoal briquettes, lamp black and carbon.

2. Wood Pelletization

By densification the variable properties of woodwaste can be controlled to a large extent for use as a fuel. Amongst the densified products, pellets are the most popular industrial products, and recently its use in residential heating units appears to be growing too.

For the financial analysis of a wood pellet plant recourse has been taken to the information provided in the feasibility study of a plant to be located in Delta. Although the proposed plant is designed to use about $1.36 \times 10^6 m^3$ of woodwaste with an average moisture content of 52%, the cost estimtes information available is considered to be adequate for the situation in Williams Lake.

However, the hog fuel and transportation costs for the Delta plant are noted to be higher than that considered in the electricity generation studies in Williams Lake discussed earlier.

Feedstock - The feedstock for the plant will be obtained from the local mills. The contracts signed with the mill owners in the area guarantee them a price of \$0.27 - \$0.35 per m^3. The hog fuel will be delivered by barge and truck with the transport cost usually between \$0.53 - \$0.88 per m^3 and for another as high as \$1.15 per m^3. The average price of the

delivered hog fuel including the contract price and transportation cost is $1.11 per m^3. It is argued that there appears to be an oversupply of hog fuel in the area and the spot price is likely to be less than the contract price.

Plant Design Capacity - Excluding twenty two days for maintenance and holidays, and based on an estimated plant availability of 85 percent, the plant will operate approximately 291 days per year. The design output of the pellet plant will be:

	Capacity Tonnes of Pellets
Daily (24 hour continuous)	635
Monthly (maximum)	16,562
Annual	185,206

The processed pellets will contain 8% moisture and have a density of 640 kg/m^3 and a higher heating value of 20.5 MJ/kg.

Wood Pellet Deliveries - Transportation to Northern California buyers will be done by self-loading ship. The ship being hired has a capacity of hauling 16,335 t of wood pellets per shipload. The wood pellets will be loaded by an elevated conveyor system at the pellet plant at the rate of about 726 t/h, and it will take approximately 2 days to load the ship. Dry storage is guaranteed by the shipping company. It is anticipated that a ship load of pellets will leave the facility every 4-5 weeks. The unloading of wood pellets will be done by 2 conveyors that will dump the pellets into bins for conveying to storage

facilities. The contract cost of shipping the pellets to the California market is $6.34 per tonne.

Costs - The estimated capital costs of the project including all equipment, machinery, and buildings; moorage and dredging; engineering and development costs; the cost of business and financial services and contingency fees will be about $10,500,000 (1987 dollars).

The annual operating costs including the cost of delivered hog fuel; wages and salaries; fuel, utilities and power; maintenance and supplies; insurance and land lease and taxes will vary between $5.5 million and $6.5 million depending upon the rate of inflation.

Sales Price and Revenue - The company has one letter of commitment for sales to a California company. Taking account of the exchange rate and subtracting out the costs of delivery to California, the company will receive a price of $42.98 per tonne (Cdn. dollars). Provided they can sell all 185,206 tonnes of pellets at this price, the annual revenue will be $7,956,000 (1987 dollars).

Given the depreciation rates used and the relatively low rate of equity investment, the project presents a very attractive rate of return to investors.

Comments - Based on the information given in the report, there would appear to be a very large and growing market for wood pellets in California, and it seems that the indigenous feedstock is largely

committed. The prospect of a free trade agreement gives Canadian producers greater assurance of unimpeded access to the California market.

The major stumbling block to using the woodwaste of Williams Lake as feedstock for a pellet plant is the cost of shipping either pellets or hog fuel to the Lower Mainland. As an example of the importance of purchasing and transporting hog fuel, approximately one-third of the annual operating costs for the proposed Delta plant is incurred for delivered hog fuel. A very preliminary and crude estimate indicates that the most that could be paid for shipping pellets from Williams Lake to the Lower Mainland is between $1.65 and $3.30 per tonne depending upon the required rate of return and the capital recovery period.

Pollution Control Aspects - From an air pollution point of view the only source of any major contaminant emission is the boiler for steam generation to be fired mainly by pellet rejects and fines. The technology for controlling boiler emissions is well established, and the levels of contaminants eventually emitted can be maintained within the acceptable limits. Other sources of dust emission are also easily controllable. As mentioned earlier no problem is expected from wastewater and solid waste disposal.

General Comments - Because of the production cost pellets are rarely manufactured for on-site use. The enhanced density, low moisture, increased energy

content per unit mass, as well as the ease of handling, transportation and storage make it attractive as a fuel for off-site utilization, provided the cost of transportation to the market is not prohibitive.

The potential growing market for pellets in California mentioned earlier stems from the fact that several biomass energy plants there not only burn chips suitable for pulp production, but also various agricultural residues such as wallnut shell, peach stones, rice husk, vineyard prunings, etc., to meet the fuel demands in the boilers. One reported price of biomass fuel in the Bay Area is $2.09/GJ(US) compared to the delivered price of wood pellets from Delta plant of $2.03/GJ(US). If the pellets can be delivered at such a competitive price, there could also be a market for its use as a replacement fuel for high sulphur coal and oil in areas with potential acid precipitation problems.

There are several wood pellet plants in Ontario and Quebec; the products from these plants are primarily destined for pulp mills and other industries as boiler fuel. In the U.S.A. there are various types of plants for manufacturing pellets from wood and other agricultural biomass. One wood pellet plant was built in the mid 1970s in Fruitvale, B.C., but because of the marketing problem it was closed down after about 2 years.

A potentially large market for wood pellets is opening up in several states in the U.S.A., as the

concern over emissions from residential woodstoves and fireplaces grows and stricter emission regulations come into effect. New designs of appliances for efficient burning of pellets are presently being sold in several states in the U.S.A., and in Ontario.

One company in Vancouver has recently started fabricating and selling pellet-fired appliances for domestic heating purposes. Larger sizes for commercial, institutional and industrial space heating are also available. The design of these appliances is based on two-stage combustion of the pellet, and there is no build-up of creosote and no emission of smoke. Both fuel and air supplies are automatic and thermostatically controlled.

The Vancouver distributor plans to import wood pellets from Spokane, Washington. The total cost of bringing one tonne of pellets to Vancouver is estimated to be $149.00. A review of pellet prices from the manufacturers indicates a wide range from about $66.00 to $115.00 per tonne bulk, and approximately $86.00 - $165.00 per tonne bagged for retail. The cost of shipping to the market area appears to be crucial, for example it is estimated to cost about $29.00 to transport a tonne of pellets from Spokane to Vancouver by a truck. One manufacturer in Sandpoint, Idaho is reported to charge $58.00 (US) per tonne of pellet in Idaho, but about $149.00 (US) in San Francisco.

It appears that the market for wood pellets would grow in this Province too, if impetus could be provided by regulating emissions from residential wood heaters. Such a step could also encourage development of other types of pellet-fired appliances, and would undoubtedly improve the air quality in various communities in winter.

Another potential market for wood pellets in this Province can be opened up by encouraging the industrial users of fuel oil containing high sulphur, particularly in areas with an acid precipitation problem. Oil-fired boilers are not difficult to convert to burning wood pellets; in fact many industrial boilers are designed for dual fuel firing.

6.0 Constraining Factors and Policy Considerations

There are certain factors, some non-economic and others economic, which could constrain the implementation of any of the options discussed in the earlier section. Several of these economic constraints identified are due to current policies and regulations which may need some adjustments to resolve this particular problem.

Although the huge loss of energy through the incineration of wood residues is a recognized fact, one major barrier towards the recovery of the energy has been easy access to alternate energy supplies. There

does not appear to be any technological and environmental constraint to woodwaste utilization options discussed earlier. The economic and related constraints are as follows:

Existing Energy Prices - The historical low prices of natural gas and electricity in the Province have discouraged utilization of indigenous woodwaste for electricity, lumber drying, space heating and other energy uses at most of the mills. It is quite likely that if the prices of alternative energy were higher, there would be more woodwaste uses at the source.

Any encouragement towards more use of woodwaste instead of natural gas and electricity should be a province-wide policy. Section 8(1)(f) of the Waste Management Act could be applied, if necessary.

Electricity Purchase Policy of BCHPA - The present policy of BCHPA regarding electricity purchase from private producers is also recognized to be a major deterrent to power generation from woodwaste in the Province.

In order to make the parallel generation or cogeneration of electrical energy from woodwastes attractive to private producers, it would be necessary for BCHPA to guarantee purchases of surplus electricity at minimum prices. BCHPA would have to be willing to enter into agreements to fill its forecast system deficit through assured purchases for a specified time period. Since steam turbine/generators may involve lags of 4-5 years

steam turbine/generators may involve lags of 4-5 years from planning stage to start-up date and have a productive life of twenty years or more, this could involve lengthy contract periods.

The price that a private producer of electricity using the Williams Lake woodwaste as feedstock would have to receive varies depending upon the amount of hog fuel available and the price that has to be paid for it, the design characteristics such as pressure and temperature of the boiler, the amount of steam drawn off for process heat, the pay-back period and the required rate of return. Available evidence suggests that private producers of electricity from woodwastes in the Williams Lake area might have to receive at least 4.5¢/kwh. to make the project feasible.

Woodwaste Availability - Any major project developer must be assured of a long-term supply of the raw material. As the sawmill production, and thus woodwaste generation, suffers from certain degrees of fluctuation, other potential sources of woodwaste or a compatible fuel nearby must be evaluated for an assured supply.

In this regard, the availability of logging residues from nearby timber harvesting areas could be explored in co-operation with the Ministry of Forests and Lands and private harvesters.

Another readily available source in Williams Lake is municipal solid waste, a fuel compatible for burning with woodwaste. It is a common practice to burn a mixed fuel for steam generation, and proven systems are

available. In Williams Lake, where municipal solid waste is presently disposed of in landfills, production of steam and power may be a likely solution for the utilization of two wastes.

From environmental perspectives any utilization of logging residues in a proper combustion system would result in a significant reduction in uncontrolled emissions from slash burning in harvested areas. The burning of municipal solid waste is usually associated with emissions of some contaminants of concern such as acid gases, trace organics and trace metals. However, the state-of-the-art control technology is capable of reducing such emissions to acceptable levels. The disposal of residues from a mixed-fuel boiler would, however, require careful evaluation, as the ash from municipal waste may have certain undesirable characteristics.

Steam Uses - To extract the maximum available energy, a cogeneration facility is recognized to offer the best opportunity in the long run. The success of such a facility depends on the diverse use of steam. In Williams Lake the major industrial users of steam could be the sawmills where it could replace natural gas and electricity presently consumed in lumber drying and space heating. Outside the mills steam may be used for district heating, commercial and institutional uses. Any such steam sales will generate revenues and reduce the operating costs.

Transportation Cost - This has been identified as a constraint to utilization of woodwaste for pellet

production. The most convenient method of transporting either the woodwaste or pellets, depending on where a plant is built, would be by rail. Therefore, the freight charge by B.C. Railway has to be a realistic one as discussed earlier.

Emissions from Residential Wood-Heating Appliances - To pave the way for wood pellets into the domestic market and to reduce emissions of contaminants from wood-fired residential heating appliances, it is essential that regulations to control such emissions should be introduced. The contaminants emitted from ordinary wood burning appliances do cause air quality problems in certain areas. Hence, some restrictions on the emission quality would encourage people to switch to wood pellets, if they are priced reasonably.

Economic Incentives - The projects under long-term options will involve substantial capital costs. It is unlikely that many investors would be able to undertake such investments or be willing to undertake the investment unless they were quite certain of a reasonable rate of return. It may be necessary to offer subsidized or guaranteed loans to make such ventures feasible.

In this respect it may be worthwhile to seek assistance from the federal incentive programs such as Alternate Energy Development Program and Bioenergy Development Program.

7.0 Conclusions and Recommendations

Large volumes of woodwaste disposal by incineration in a number of wigwam burners is contributing to the air quality problem in Williams Lake. The situation will deteriorate further unless this outdated practice of burning woodwaste in nearly obsolete equipment is discontinued.

There is no technological barrier towards resolution of this problem by alternative uses of this material. The major constraints to such practices are identified to be shortsighted attitude, institutional barriers and certain existing policies and regulations. Because of the circumstances, such as vast resources and availability of relatively cheap energy, the residues from the forest products industry are still regarded as a "waste" to be disposed of. This attitude has so far stymied proper utilization of this material, which is nothing but a valuable resource; and any attempt in the past to do that appears to have been thwarted by several existing policies and regulations.

Nearly all previous investigations have dealt with the economics of steam and electricity generation from woodwaste, and have reached a common conclusion of high capital investment and a higher price of electricity than what BCHPA is willing to pay. However, none of these studies seem to have considered in any detail the costs associated with the overall environmental and social benefits, which are not readily quantified, because of the discontinuation of incineration and the

postponment of any displaced power generation by conventional means. In an overall sense by disposing of the woodwaste, particularly by incineration, the society as a whole may be missing an economic opportunity.

In view of the above the following recommendations are made for both short- and long-term measures which could be taken to reduce emissions from the woodwaste burners. It should be noted that the short-term measures are to provide a "breathing space" while developing a long-term strategy.

1. The Regional Manager should set-up a time table in consultation with each millowner for concrete steps to be taken to implement one or more of the near-term options outlined in Section 5 or any other suitable measures.

2. The Permittees must adhere to the time table agreed upon to bring their burner emissions in compliance with the Permits. Any failure to do that should call for appropriate actions under the Act.

3. Continue monitoring of the temperature and opacity of the burner emissions as well as of the air quality parameters to determine any improvement in the situation.

4. In order to avoid any perceived discrimination against these mills and to allay any fear of them being put at a disadvantage economically, a general policy on the uniform province-wide application of

Section 8(1)(f) of the Act or any regulations on the utilization of woodwaste should be considered.

Two long-term options discussed in this report should not be regarded as the panacea for the problem of surplus woodwaste in Williams Lake, although they have good potential for application. Considering the quantity of woodwaste available in the area, multiple uses may offer more advantages than a single purpose facility. In any event the following measures should be considered for implementing a long-term strategy.

1. As the federal Department of Energy, Mines and Resources (EMR) has an active program on biomass energy for more than a decade and accumulated useful information on woodwaste conversion, their co-operation should be sought in developing a long-term strategy for Williams Lake.

   A computer model to simulate bioenergy conversion systems has been developed for EMR, which could prove useful in the selection of suitable options.

2. Any investigation into long-term options must be carried out jointly with other Ministries, in particular the Ministry of Energy, Mines and Petroleum Resources, Ministry of Forests and Lands, and Ministry of Economic Development.

3. A review of the existing energy policies on both generation and sale of electricity by small producers should be undertaken.

4. The federal government could be requested to provide financial incentives to prospective developers through their programs such as Bioenergy Development Program and Alternate Energy Development Program.

5. If the viability of a wood pelletization option hinges soley on the transportation cost of the product or raw materials, then B.C. Railways may be approached for reevaluation of the freight cost.

6. The Ministry should initiate necessary actions to:
   - develop a policy and guidelines for emissions from residential heating appliances firing wood and wood-derived fuel;
   - develop policies and guidelines for emission from open burning of log yard residues, timber harvesting residues, and agricultural residues;
   - revise the pollution control objectives for wood- and wood-derived fuel-fired power boilers, and develop new ones for wood- and wood-derived fuel-fired industrial boilers and combustors, wood pellet plants, charcoal production, wood pyrolysis, gasification and liquefaction, and for alcohol production.

7. The Ministry should encourage the industries located in areas with potential acidic precipitation problem to replace high sulphur containing fuels used in boilers by wood or wood-derived fuel.

8. Develop a long-term strategy for the utilization of residues from forest products industry in the Province.

APPENDIX

Partial List of Studies Completed Under Bioenergy Development Program of Department of Energy, Mines and Resources

Program and General Information

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A Benefit/Cost Evaluation Model for Federally Supported Bioenergy Projects. McDaniels Research Ltd., Vancouver, B.C. Ottawa: Energy, Mines and Resources. 1983.

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Cost Benefit Analysis of Gas for Drying of Wood Waste Feedstocks. Sandwell & Comany Ltd., Vancouver, B.C. EMR: RED-ENFOR C-96/BDP. 1980-1981.

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Bin and Silo Design and Biomass Materials. B.C. Research, Vancouver, B.C. EMR: RED-ENFOR C-130/BDP. 1980-1981.

Production of Finely Divided Wood Particles for in-Feed to Suspension Burners and Gasifiers. John Stone & Associates Ltd., Aylmer, Quebec. EMR: RED-ENFOR C-144/BDP. 1980-1981.

Advanced Feedstock Preparation System for Large-Scale Hog Fuel Boilers. Industrial Process Heat Engineering Ltd., Vancouver, B.C. EMR: RED-ENFOR C-149/BDP. 1980-1981.

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